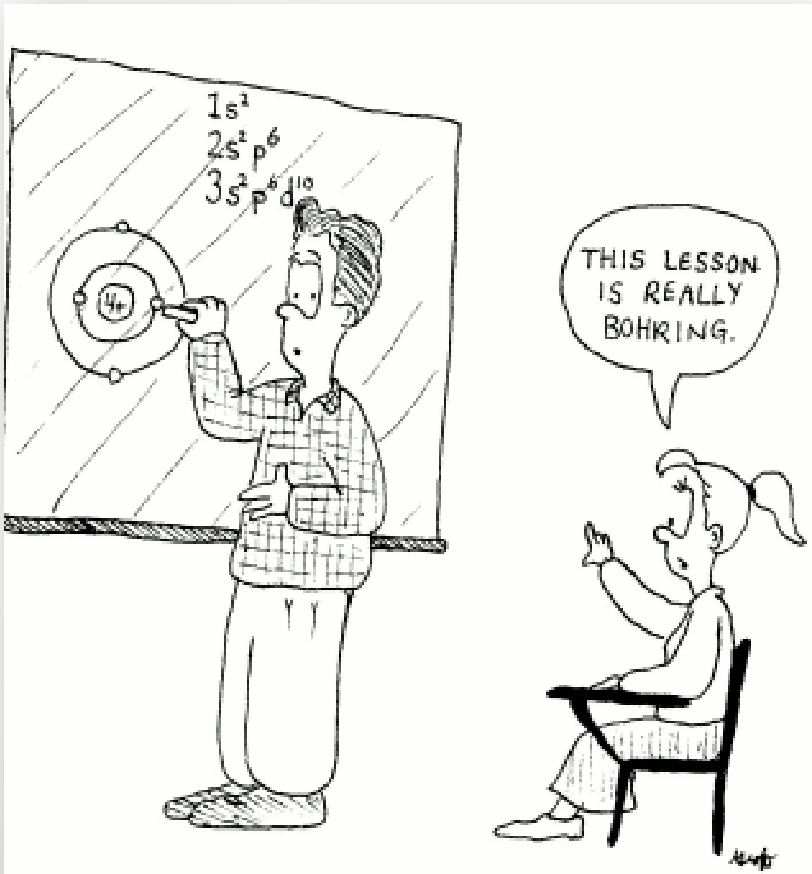
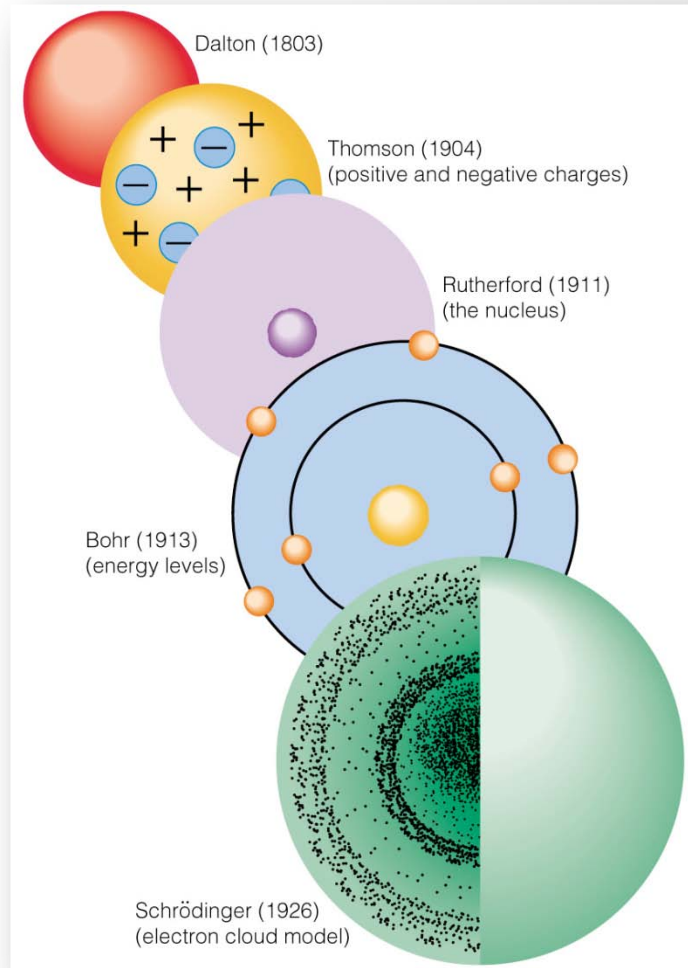
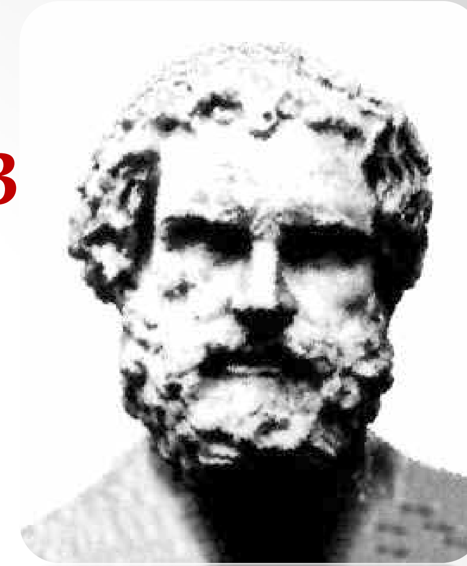
T02D01 – Atomic Theory☺





Democritus - Greek philosopher ~460 B



a) matter is composed of tiny
   particles called atoms
   which could not be subdivided
   or made any smaller

b) atoms were different only in size and shape

c) atoms were in constant motion

d) atoms were able to join with other atoms
   to form different types of matter

John Dalton, 1766-1844

English chemist, Fellow of the Royal Society

a) matter is composed of tiny
particles called atoms

b) atoms of a particular element
are alike in size, shape,
and weight but differ from
atoms of other elements

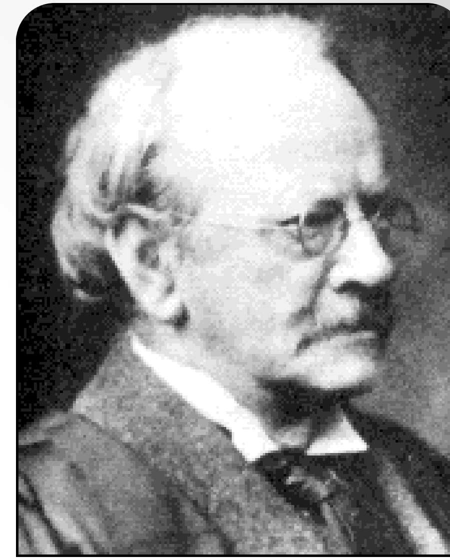
c) during chemical changes, atoms of different elements
unite forming molecules (compounds)

d) during these chemical changes, atoms themselves
do not change, that is, are not broken down

e) when atoms combine, they do so in definite
whole number ratios by weight (Law of Definite Proportio

J. J. Thomson -

Gas tube experiments, late 1800's



J.J. Thompson

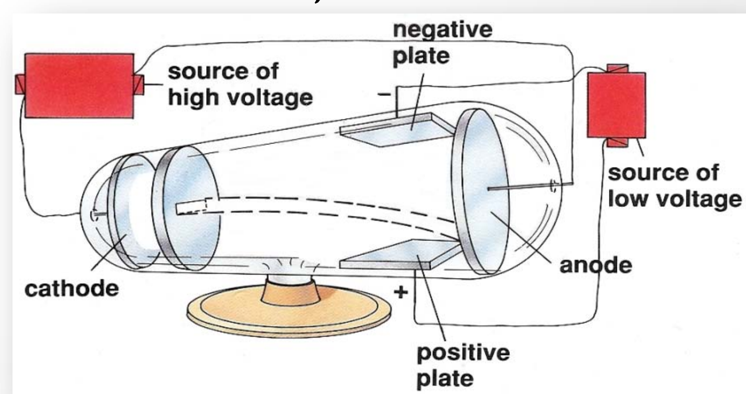
a) High voltage across electrodes
in a vacuum: sees electrical discharge.

b) Cathode rays cast a well defined
shadow: must travel in straight lines.

c) Rays deflected by magnetic and
electrical fields: So! they must be electrical
charges in motion.

d) Direction of deflection indicated charge was negative.

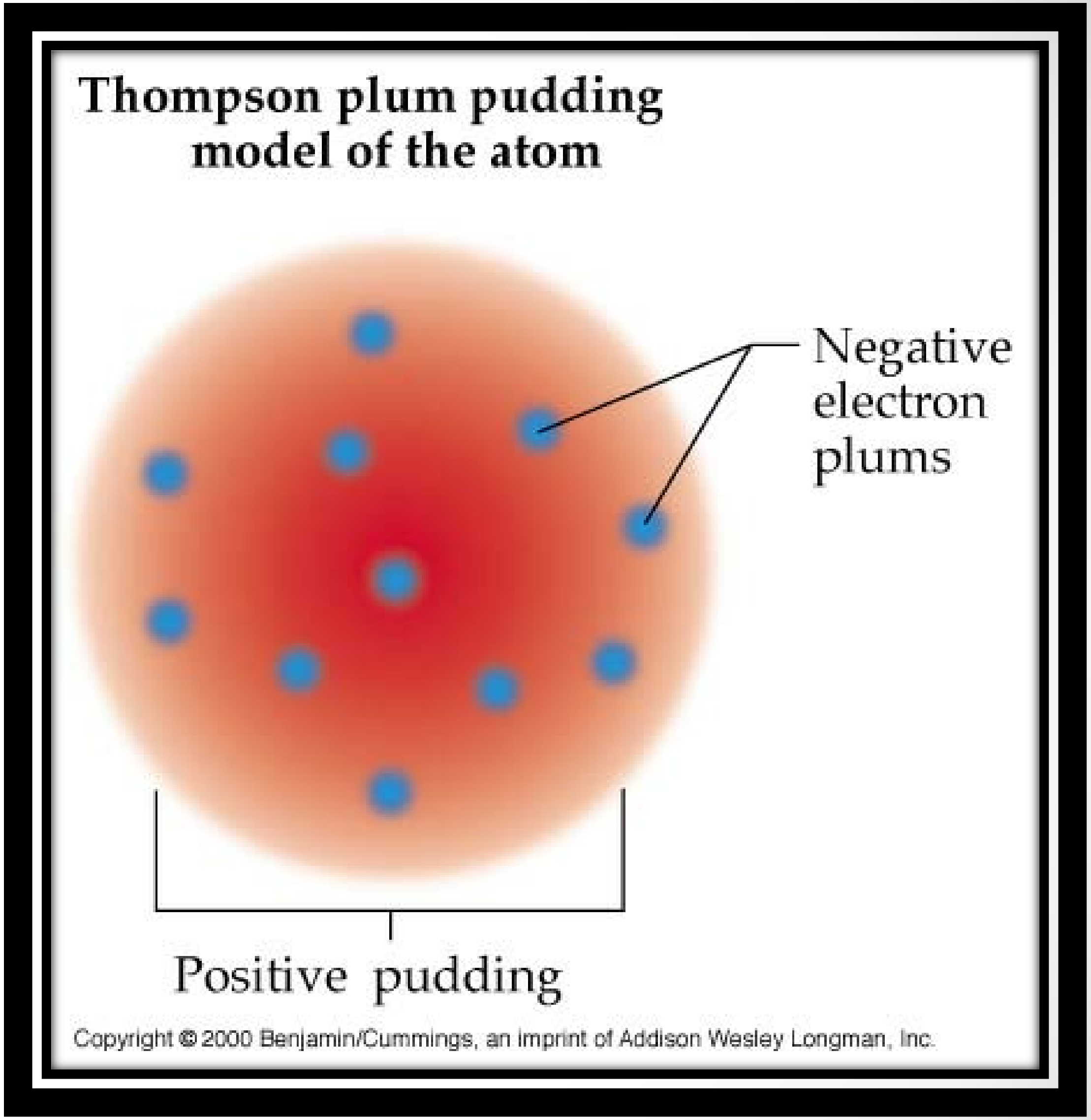
e) Able to measure electron charge to mass ratio, *e/m*.



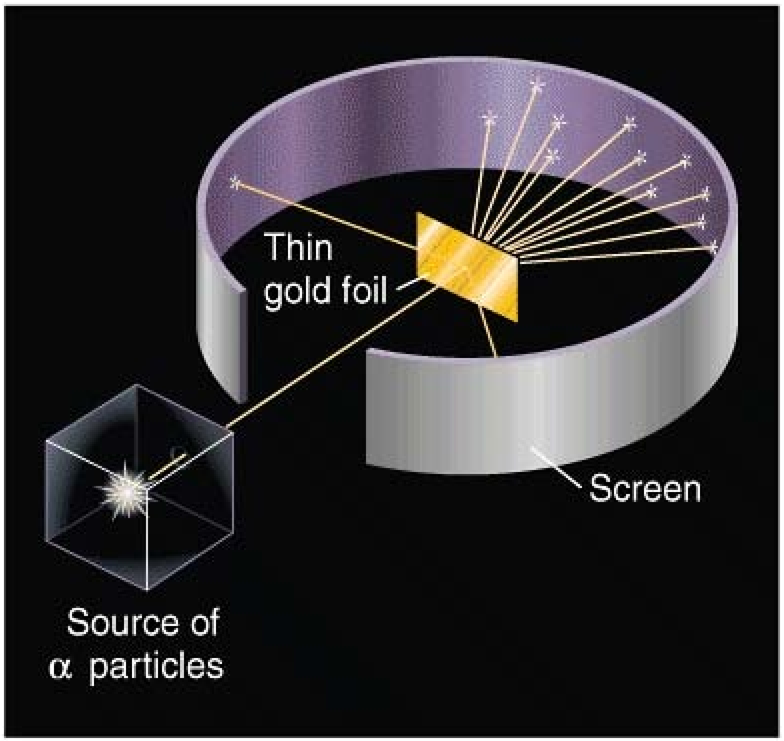
So! Thompson has discovered the ***electron***, and it must live inside atoms.

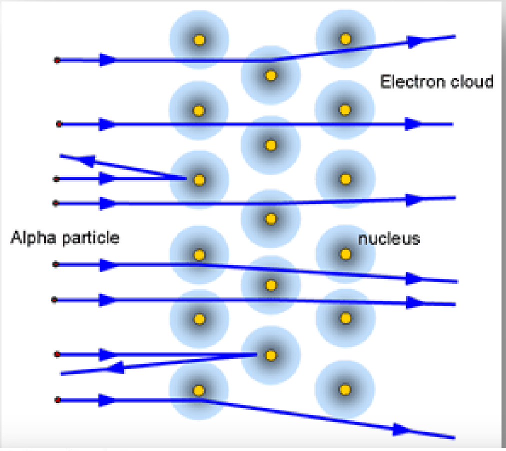
It is much less massive than the the atom itself, so perhaps we have little electrons stuffed into the 'rest' of the atom like raisins in the oatmeal, or:

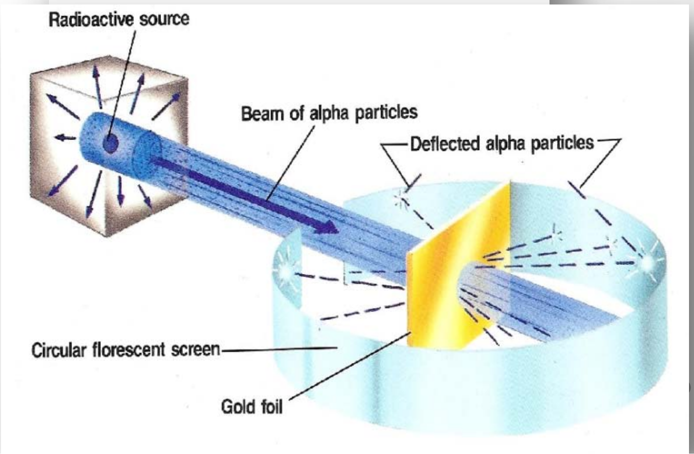
Plum Pudding...



Rutherford's Gold Foil - Scattering Experiment







ZnS Screen:

- ***Backscattered*** flashes

Rutherford Concludes in 1913:

1. The atom contains a tiny dense center called the nucleus whose volume is about 1/10 trillionth the volume of the atom.

2. The nucleus is essentially the entire mass of the atom.

3. The nucleus is positively charged: the amount of positive charge of the nucleus balances the negative charge of the electrons.

4. The electrons move around in the **empty space** of the atom surrounding the nucleus.

Atoms are subdivided into more fundamental units:

Electron identified in 1897 by J. J. Thomson (1856-1940)
Carries unit of negative electrical charge
Mass is about ~1/2000th that of proton.

Proton identified in 1919 by Rutherford
Principal constituent of nucleus
Carries unit of positive electrical charge
Mass is 1836 times that of electron

Neutron is later identified in 1932 by Chadwick:
Another primary particle in nucleus
Carries no net electrical charge
Mass is approximately that of proton

***BUT*:**

There is a big beef here between this model and classical (Newtonian) physics and well-established electrodynamics.

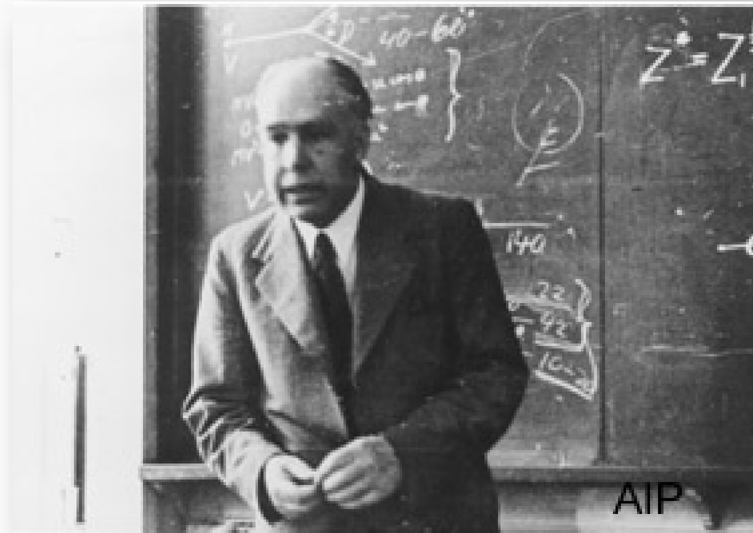
If the atom is like this little solar system, with electrons spinning around the protons (where the centripetal forces on the electron presumably balance the electrostatic attraction to the protons), classical theory definitely states that the electron should

RADIATE ENERGY

and therefore slow down and crash into the nucleus!

This is a Big Deal. When the problem is solved, things will never be the same ...

Niels Bohr 1913, to the rescue:
Theory for orbits ("states")
of electrons in atoms:



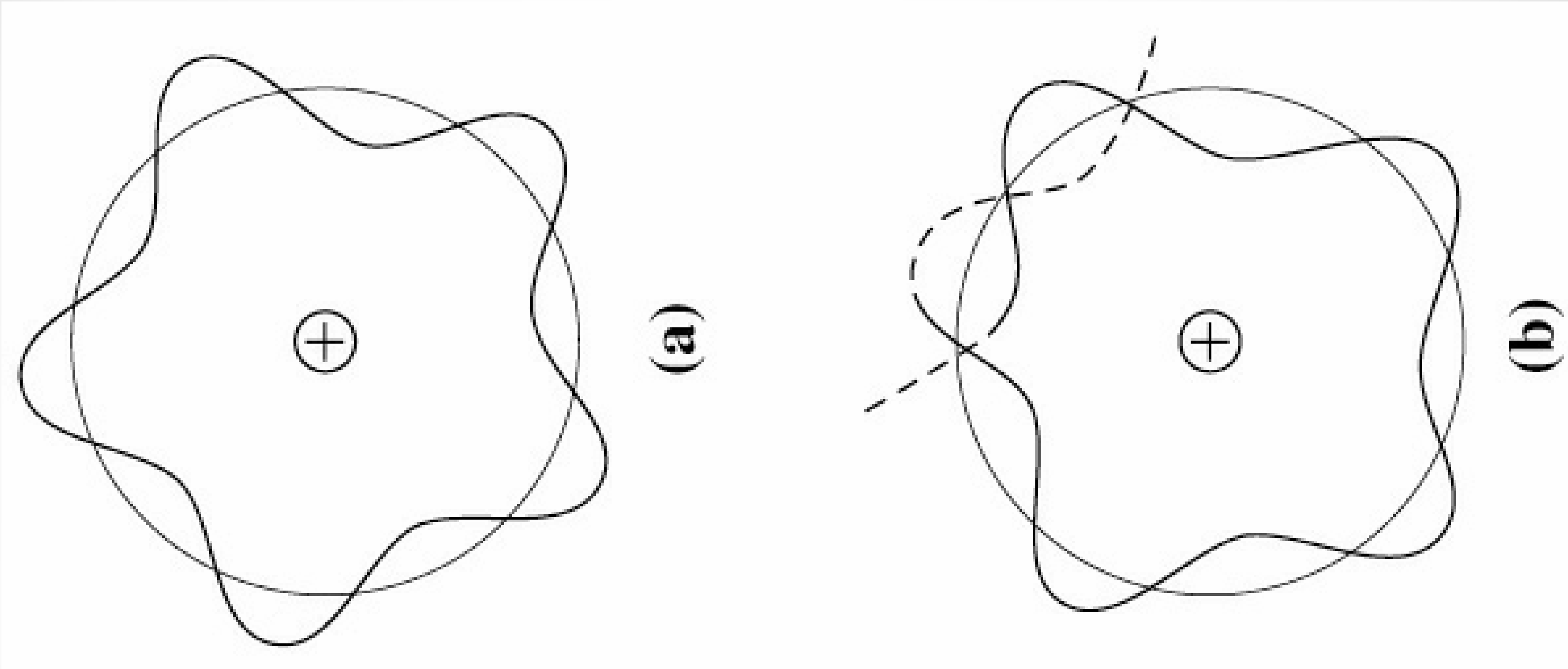
1.Electrons have certain allowed states
in which they can move
without radiating.

2.The allowed states have well-defined ('quantized') energies
that can be determined with normal classical physics.

3.In an allowed state the electron's angular momentum, ***mvr***, must be
of the form:

$$mvr = n\, h/(2p)$$

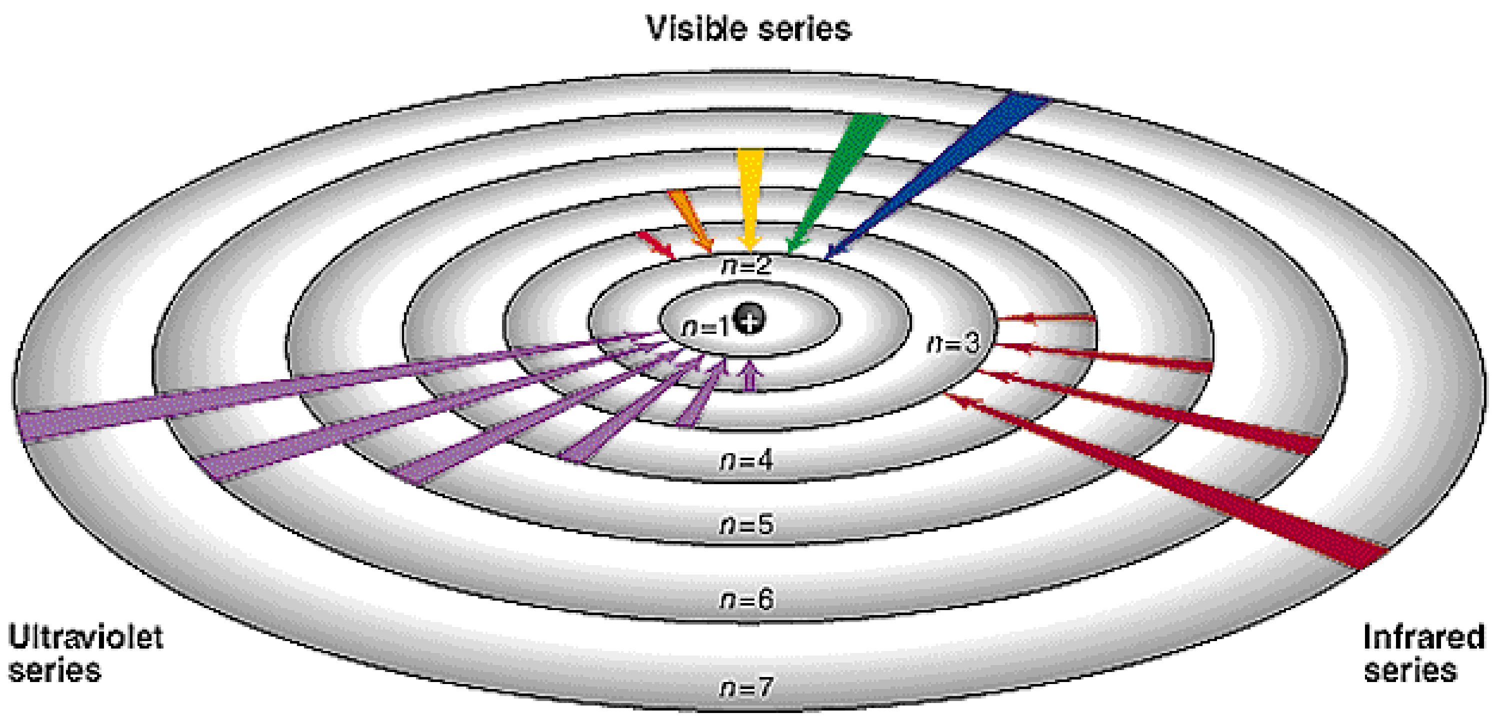
where ***n*** = 1, 2, 3....,
h is Planck's constant , ***m*** is the electron mass,
v and *r* are its velocity and the radius of its orbit.



What Bohr is saying is that it is only when the electrons have certain special energies, such that their wave character is perfectly self-reinforcing, can they orbit the nucleus without radiating away their energy.

This is the birth of *Quantum Mechanics*.

Bohr's brilliant insight is immediately able to explain the observed frequencies of the emission spectrum of atomic hydrogen.

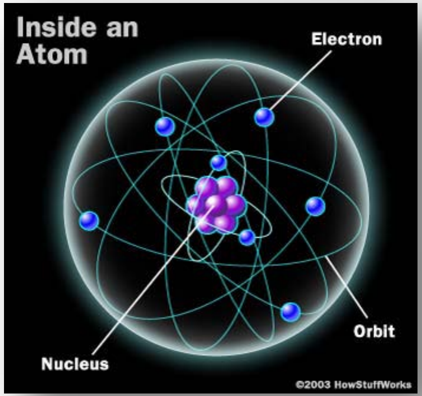


Schrödinger's (Quantum Theory) model:

Allows the electron to occupy three-dimensional space.

Requires three coordinates, or three **quantum numbers** to describe the **orbitals** in which electrons can be found.

The quantum numbers describe the size, shape, and orientation in space of the orbitals on an atom.
Think of the orbitals as a cloud of negative charge.



The **principal quantum number (n)** describes the size of the orbital and indirectly describes the energy of an orbital.

The **angular quantum number (l)** describes the shape of the orbital.

The **magnetic quantum number (m)** describes the orientation of a particular orbital. (It is called the magnetic quantum number because its effect was first observed in the presence of a magnetic field.)

A fourth quantum number, the **spin quantum number**, allows two electrons of opposite spin into each orbital.

PERIODS -

Similarities: The number of outer electron shells.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Se	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds								

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

GROUPS –

Similarities: The number of electrons in the outer shell. Common reactivity, bonding, chemical and physical properties.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Se	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds								

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

METALIC PROPERTIES

Similarities: An elements relative ability to conduct energy in the form of heat or electricity.

Non Metal s

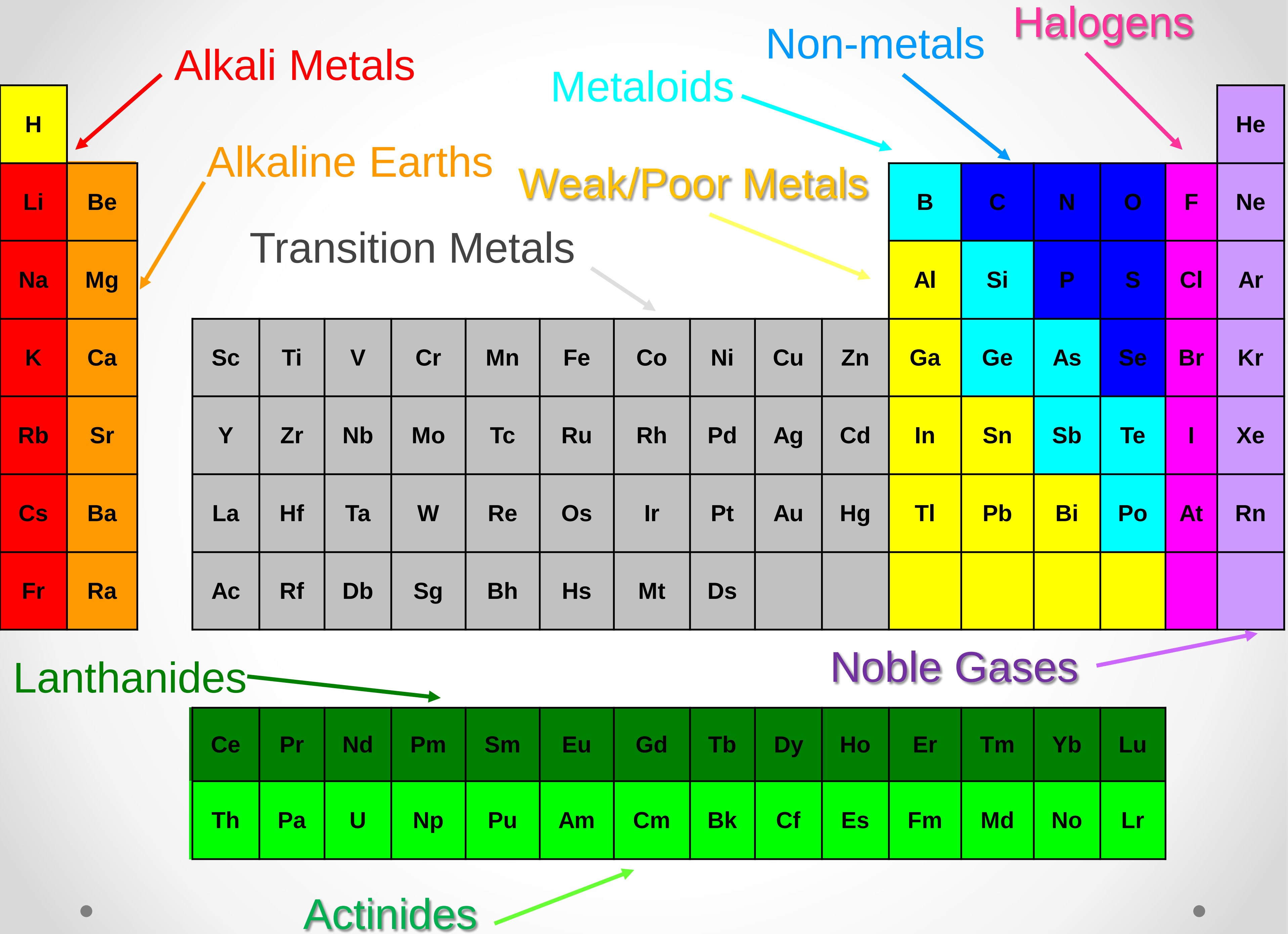
The

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Se	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds								

Metal s

Metal oids

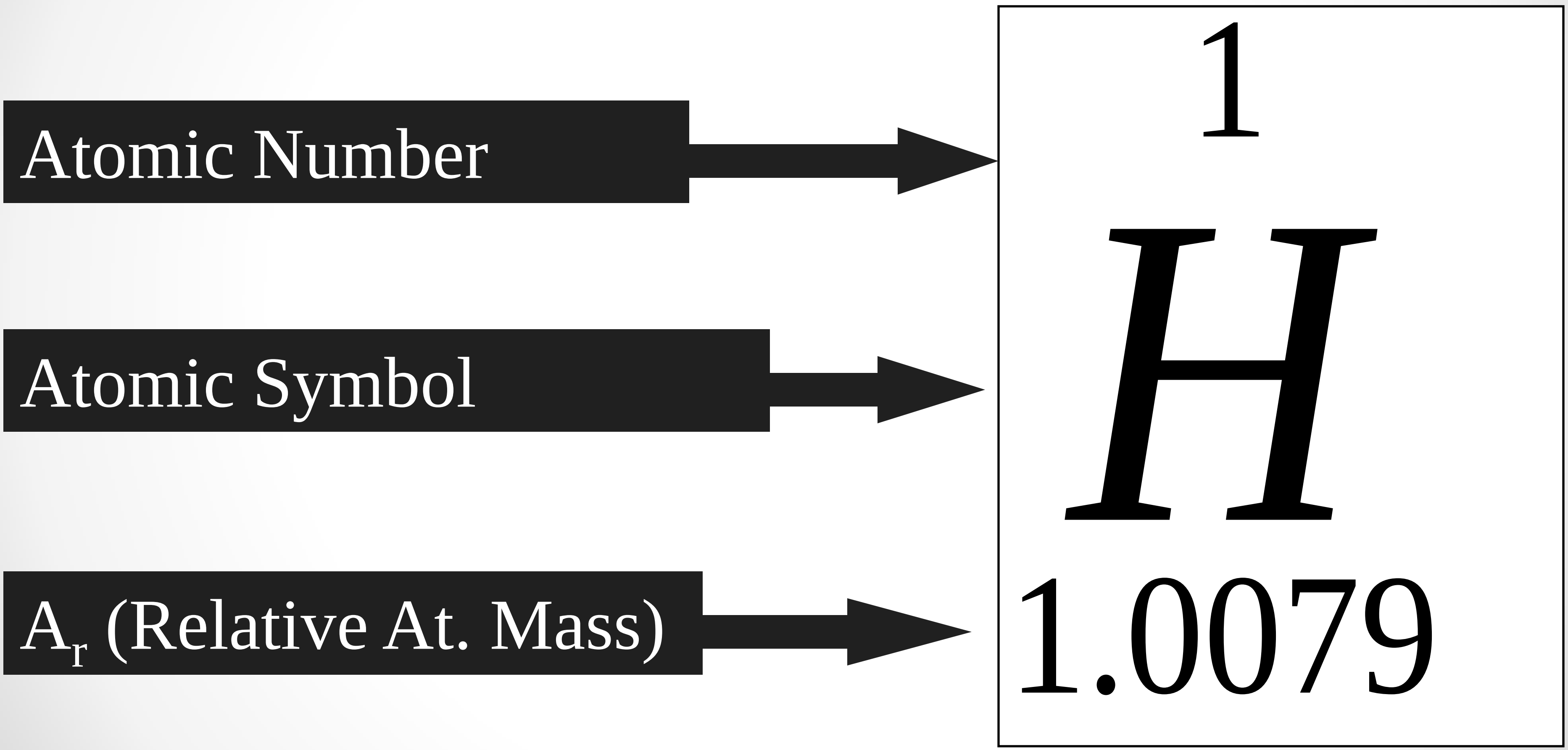
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

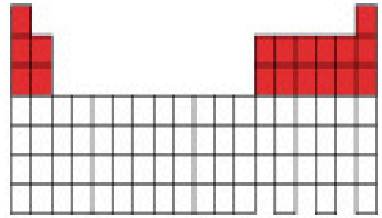


Alkali Metals
Metaloids
Non-metals
Halogens
Alkaline Earths
Weak/Poor Metals
Transition Metals
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac Rf Db Sg Bh Hs Mt Ds
Lanthanides
Noble Gases
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr
Actinides

On the Periodic Table:

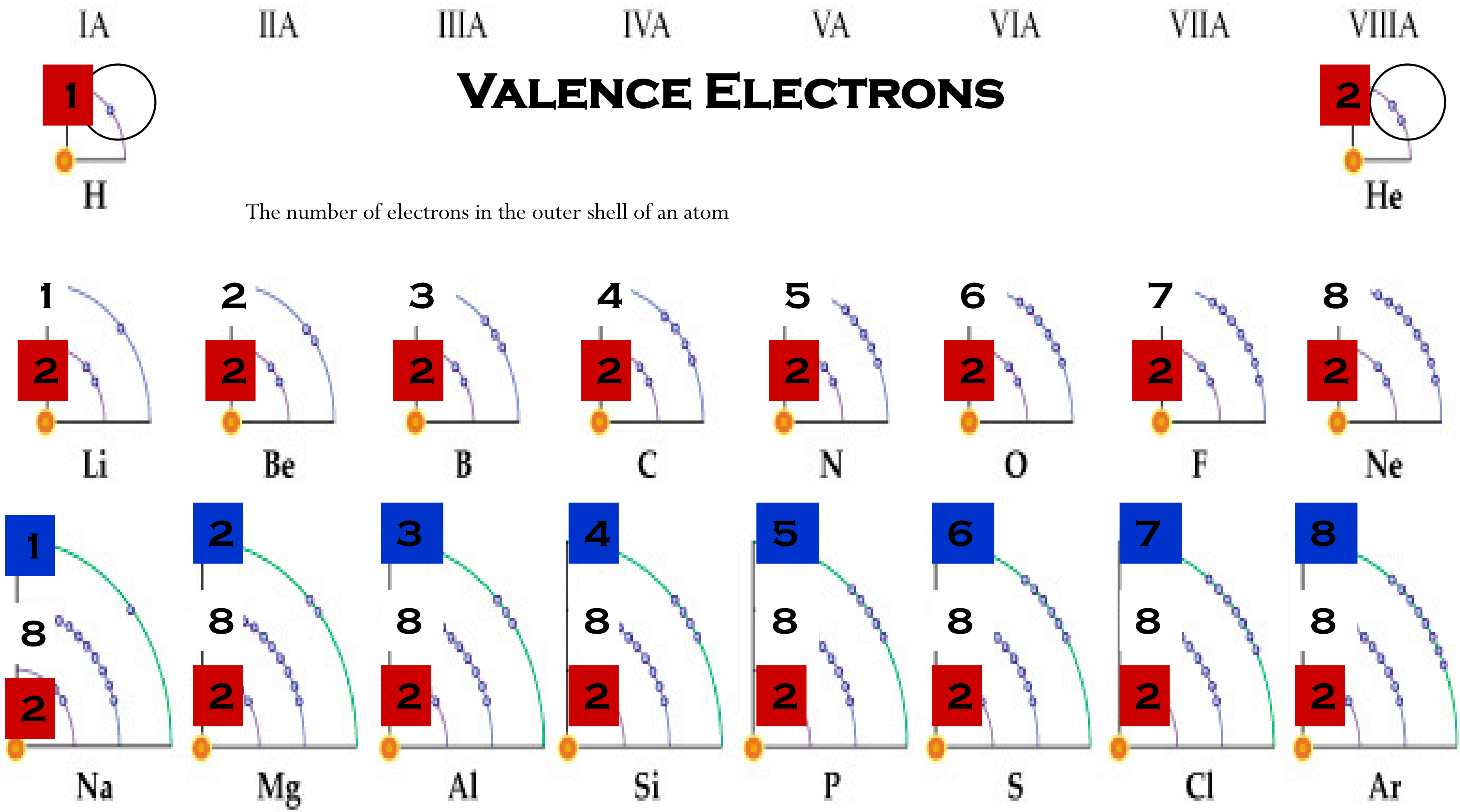
What do the numbers mean?



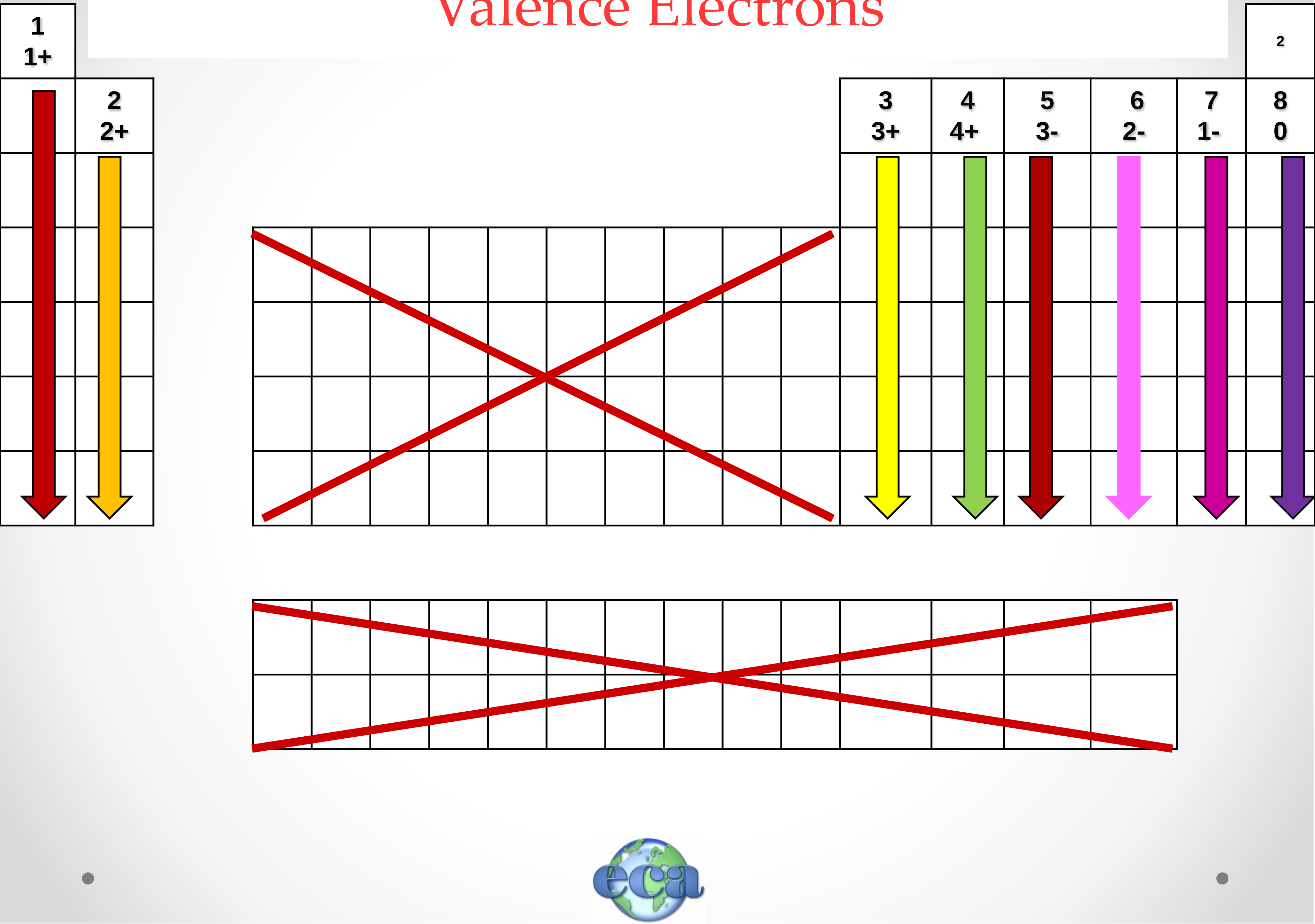


Valence Electrons

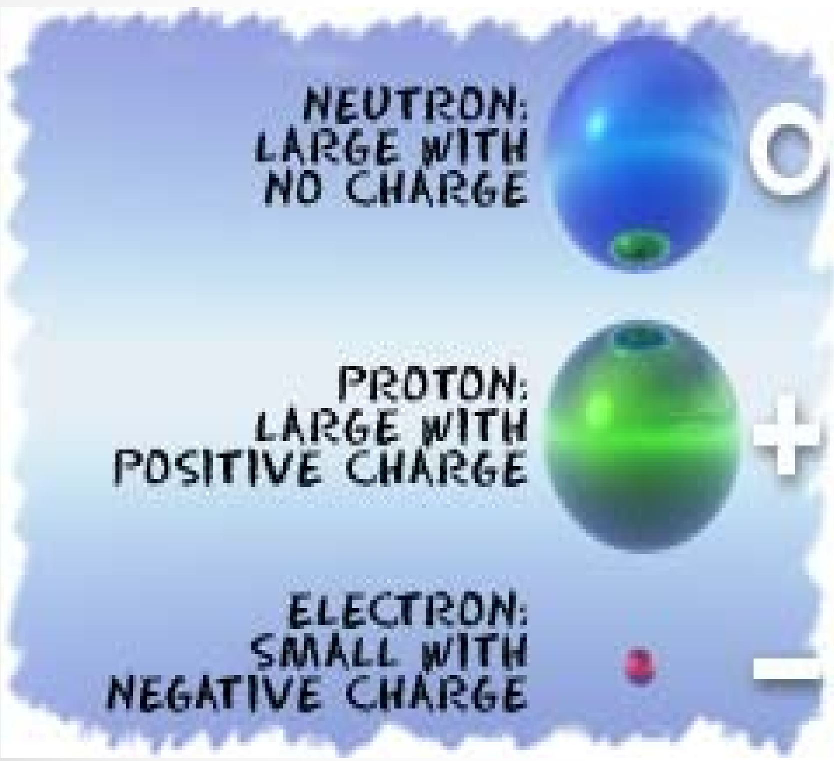
The number of electrons in the outer shell of an atom



Valence Electrons



Three charges of an atom…



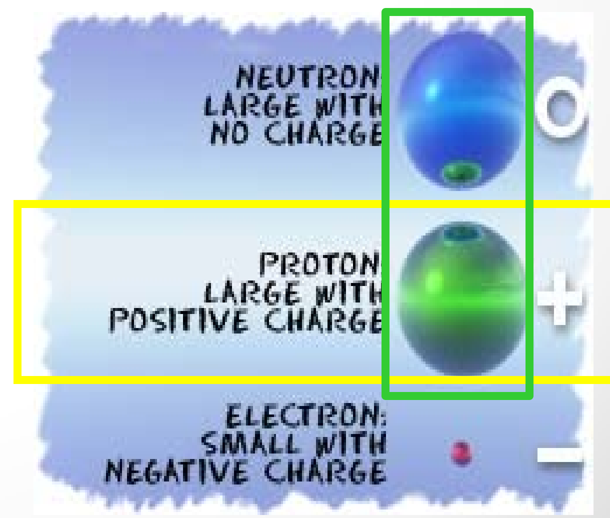
Sub-atomic particles	Mass in g	Charge in C
Proton, p^+	1.7×10^{-24}	1.6×10^{-19}
Neutron, n	1.7×10^{-24}	0
Electron, e^-	9.1×10^{-28}	1.6×10^{-19}

Atomic Number

- Number of protons contained in an atom (p)
- Determines the element
- Every element of that kind has the same number of protons

Mass Number

- Number of protons and neutrons in an atom (p + n)
- Can change for various isotopes

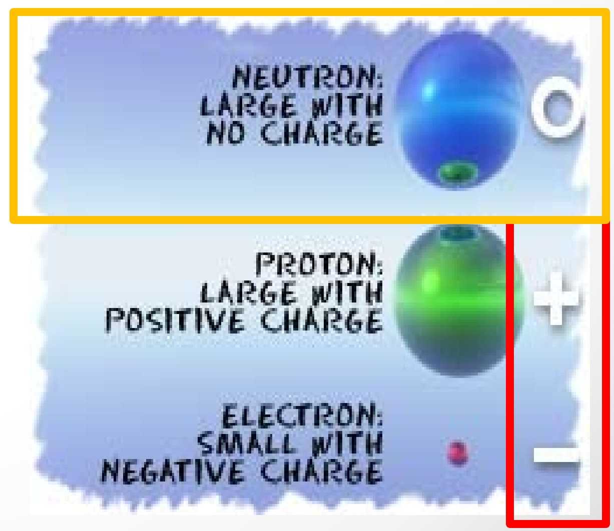


Ions

- Differing number electrons (e)
- Changes overall charge
- Cations (positive)
- Anions (negative)

Isotopes

- Differing number of neutrons (n)
- Changes Mass Number



Atomic Number (Z)

- Found above each element on the periodic table
  - The atomic number is defined by the NUMBER OF PROTONS
    - H (atomic # 1) has 1 proton
    - Cl (atomic # 17) has 17 protons
    - Mg (atomic # 12)
    - S
    - F
    - What element has 35 protons?

Mass Number (A)

- Protons have a mass
- Neutrons (although neutral) have a mass similar to protons
- Electrons have a mass so small we don't account for it in calculating the mass
- Therefore the mass number is the sum of all protons and neutrons within the atom

Mass Number = P + N

When to use: When determining composition of a single atom! (this is not what's on the PT)

A_r Atomic Mass / Molar Mass

Not the Mass Number!!!

- The atomic mass is the average "weighted" mass of all the isotopes of the element.
  - Example: Carbon
    - Carbon – 12 (98.9%)
    - Carbon – 13 (1.1%)
    - Carbon – 14 (Not a stable isotope)
    - (.989 x 12) + (.011 x 13) = 12.011
      - Look on your periodic table!
- When to use MM: Abundances, Stoichiometry

Isotopes

- An isotope is an element that contains a different number of neutrons and protons.
  - Affects the molar mass of the element
  - Longhand notation
    - Element – Mass Number
    - Carbon – 12
    - Carbon – 14
  - Shorthand notation

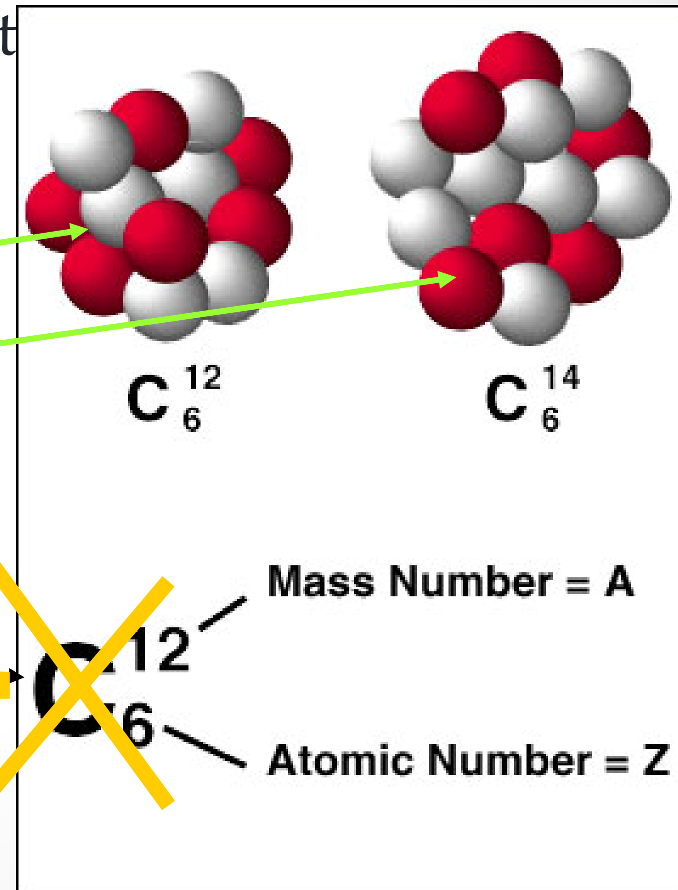
$$^{12}_{6}C^{4+}$$

Mass#

Charge

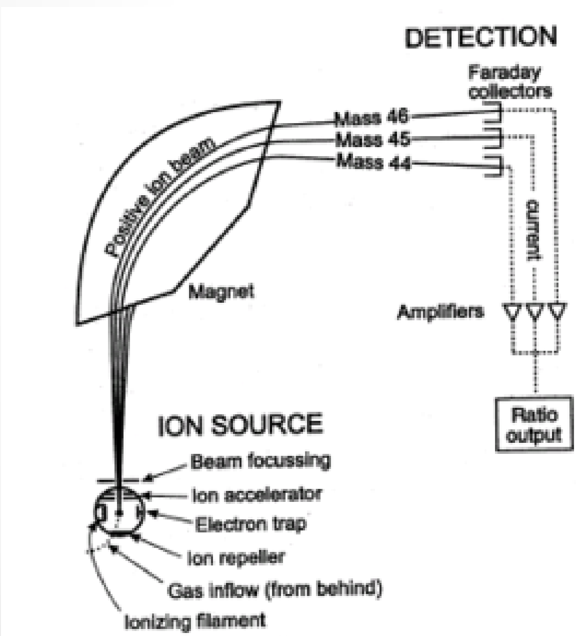
X

Atomic #



Mass Spectrometer

- The mass spectrometer is an instrument used:
  - To measure the relative masses of isotopes
  - To find the relative abundance of the isotopes in a sample of an element



When charged particles pass through a magnetic field, the particles are deflected by the magnetic field, and the amount of deflection depends upon the **mass/charge** ratio of the charged particle.

Mass Spectrometer – Questions

- A mass spec chart for a sample of neon shows that it contains:
  - 90.9% ^{20}Ne
  - 0.17% ^{21}Ne
  - 8.93% ^{22}Ne

Calculate the relative atomic mass of neon

You must show all your work!

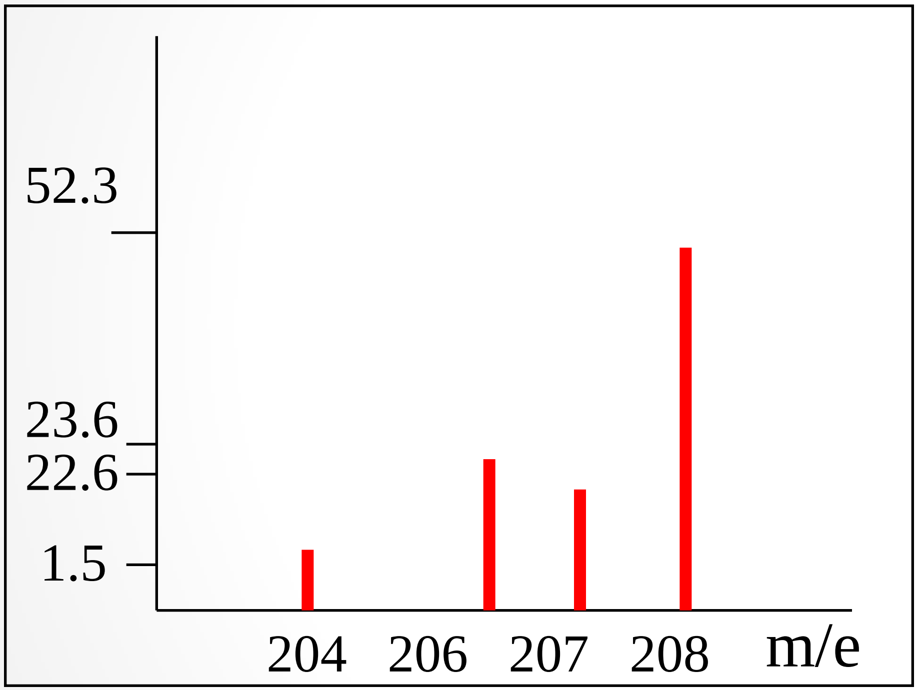
Mass Spectrometer – Questions

- 90.9% ^{20}Ne
- 0.17% ^{21}Ne
- 8.93% ^{22}Ne

$$\frac{(90.9 \times 20) + (0.17 \times 21) + (8.93 \times 22)}{100}$$

$A_r = 20.18$

Mass Spectrometer – Questions



Calculate the relative atomic mass of lead

You must show all your work!

Mass Spectrometer – Questions

- 1.5% ^{204}Pb
- 23.6% ^{206}Pb
- 22.6% ^{207}Pb
- 52.3% ^{208}Pb

$$\frac{(1.5 \times 204) + (23.6 \times 206) + (22.6 \times 207) + (52.3 \times 208)}{100}$$

$$\frac{306 + 4861.6 + 4678.2 + 10878.4}{100} \qquad \frac{20724.2}{100}$$

$A_r = 207.24$

Ions – Anions/Cations

- Anions (non-metals)
  - An atom with a net negative charge
    - More electrons than protons
    - Br^- contains 35 protons, 36 electrons (-1)
- Ca+ions (metals)
  - An atom with a net positive charge
    - More protons than electrons
    - Mg^{2+} contains 12 protons, 10 electrons (+2)